DOCUMENT RESUME

ED 103 403 SP 009 010

AUTHOR	Dansereau, Donald F.; And Others
TITLE	Learning Strategies: A Review and Synthesis of the Current Literature.
INSTITUTION	Texas Christian Univ., Fort Worth. Inst. for the Study of Cognitive Systems.
SPONS AGENCY	Air Force Human Resources Lab., Brooks AFB, Texas.
REPORT NO	AFHRL-TR-74-70
PUB DATE	Dec 74
NOTE	92p.
EDRS PRICE	MF-$0.76 HC-$4.43 PLUS POSTAGE
DESCRIPTORS	Academic Aptitude; Cognitive Ability; Comprehension; Creativity; *Educational Research; *Individual Differences; *Learning Processes; Memory; *Psychological Studies

ABSTRACT

This report reviews and synthesizes psychological and educational research on learning strategies. The report contains an overview of strategy modification; a review of factors influencing strategy selection and use (including intellectual aptitude, personality variables, cognitive style, reception preference, motivation, sex, and prior knowledge); a review of learning strategies (general, comprehension, memory, problem solving, and creativity); and recommendations involving future research. This report develops and uses a conceptual framework providing coherence to the variety of studies which relate to research on learning strategies. The intent of this study is to provide a basis for developing specific research plans to improve students' learning strategies and skills. (Authors)

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LEARNING STRATEGIES: A REVIEW AND SYNTHESIS OF THE CURRENT LITERATURE

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This interim report was submitted by the Institute for the Study of Cognitive Systems, Texas Christian University, Fort Worth, Texas 76109, under contract F41609-74-C-0013, project 1121, with Technical Training Division, Air Force Human Resources Laboratory (AFSC), Lowry Air Force Base, Colorado 80230. Dr. Gerard Deignan and Dr. Ronald Spangenberg, Instructional Technology Branch, shared the contract monitorship.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFHRL-TR-74-70
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): Learning Strategies: A Review and Synthesis of the Current Literature
5. TYPE OF REPORT & PERIOD COVERED: Interim
6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): Donald F. Dansereau, Gary L. Long, Tomme R. Actkinson, Barbara McDonald
8. CONTRACT OR GRANT NUMBER(s): 62703F; F41609-74-C-0013

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Institute for the Study of Cognitive Systems, Texas Christian University, Fort Worth, Texas 76109
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 1121-01-19

11. CONTROLLING OFFICE NAME AND ADDRESS: Hq Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235
12. REPORT DATE: December 1974
13. NUMBER OF PAGES: 92

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Technical Training Division, Air Force Human Resources Laboratory, Lowry Air Force Base, Colorado 80230
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This is an interim report resulting from a follow-on contract. Findings under the original contract are documented in AFHRL-TR-73-51(I) and AFHRL-TR-73-51(II) (contract F41609-73-C-0023).

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

learning strategies
information processing (human)
individual differences
technical training
personality variables
cognitive style
reception preferences
comprehension strategies
memory strategies
problem solving
creativity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report reviews and synthesizes psychological and educational research on learning strategies. The report contains an overview of strategy modification; a review of factors influencing strategy selection and use (including intellectual aptitude, personality variables, cognitive style, reception preference, motivation, sex, and prior knowledge); a review of learning strategies (general, comprehension, memory, problem solving, and creativity); and recommendations involving future research. The report develops and uses a conceptual framework providing coherence to the variety of studies which relate to research on learning strategies. The intent of this study is to provide a basis for developing specific research plans to improve students' learning strategies and skills.

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Summary

Problem

The way students of equal ability select and use differing information processing strategies has been correlated with consistent performance differences. Information processing strategies may be more critical than natural ability for learning. Thus, training in how to select and use more efficient techniques and strategies for selecting, storing, manipulating, and outputting information should help performance in learning. Identifying and validating information processing strategies which can be used by Air Force students in technical training should enable improved levels of student learning performance and transfer of training to the job.

Approach

A literature review covering learning strategies which involve information selection, storage, manipulation and outputting was conducted. This review examined factors which research has suggested may influence strategy selection and use. Learning strategies were reviewed and analyzed. Recommendations based on the literature review were provided.

Results

A report reviewing and synthesizing psychological and educational research on learning strategies is presented as a basis for developing research for improving student's learning strategies and skills. The report contains: an overview of strategy modification, a review of factors influencing strategy selection and use (including intellectual aptitude, personality variables, cognitive style, reception preference, motivation, sex, and prior knowledge), a review of learning strategies (general, comprehension, memory, problem solving and creativity), and recommendations involving future research. This report develops and uses a conceptual framework providing coherence to the variety of studies which relate to research concerning learning strategies.

Conclusions

The review of the literature provides a quick insight into the state-of-the-art concerning learning strategies. It will be most beneficial in developing research for testing selected information processing strategies for use by students in Air Force technical training.

PREFACE

This report documents a survey of the literature pertaining to learning strategies. Research was accomplished under Project 1121, Advanced Technology for Air Force Technical Training. Dr. Marty R. Rockway was the Project Scientist, Dr. Gerard Deignan was the Task Scientist until 1 June 1974, and Dr. Ronald Spangenberg was the Task Scientist from 1 June 1974 to the present.

Research contained in this report was conducted under the provisions of Contract Number F41609-74-C-0013 with Texas Christian University, Institute for the Study of Cognitive Systems, Fort Worth, Texas, 76129. Dr. Donald Dansereau was the Principle Investigator. This research is based upon previous work performed by the contractor under Contract Number F41609-73-C-0023 which resulted in the publication of AFHRL-TR-73-51(I), Factors Related to Developing Instructional Information Sequences: Phase I, and AFHRL-TR-51(II), Factors Relating to the Development of Optimal Instructional Information Sequences.

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LEARNING STRATEGIES: A REVIEW AND SYNTHESIS OF THE CURRENT LITERATURE

Introduction

Most educators and researchers in the area of education agree that we need to improve instructional effectiveness, especially the transferability of classroom knowledge and skills to the job situation. The Air Force and other governmental agencies have been instrumental in stimulating research to provide a basis for educational improvements. In the main, these studies and subsequent attempts at implementation have been directed toward the improvement of teaching. That is, this research has been designed to ferret out ways of presenting information to students that will optimize their performance on a variety of criterion measures. The advent of computer assisted and computer managed instruction has provided the flexibility necessary to tailor these empirically derived teaching methods to individuals, thus dramatically improving the chances for successful implementation.

The extensive efforts directed at improving teaching methods, have overshadowed the few scattered attempts at developing a basis for improving students' learning strategies and skills. As we will argue, the relative neglect of the learning side of the educational coin is probably totally unwarranted and should be remedied as quickly as possible. Teaching and learning strategies need to be developed in concert, consequently, due to previous emphasis on methods, research on learning strategies needs to be brought "up to speed." The present review and synthesis of psychological and educational research on potentially relevant strategies is a small step in this direction.

Because most of the work on strategies is recent, the bulk of the literature covered in this review was published during the period from 1967 to the present. This research is extremely diverse in its conception,

and much of it is at such a basic level that it will be necessary to extend and expand it prior to educational implementation. One of the major contributions of this review and synthesis is the development of a conceptual framework within which these diverse studies can be placed. This framework appears to add a coherence to the literature that has been previously missing. The following major topics will be covered in this report:

Manipulation of the Educational Environment Versus Manipulation of the Student.

Manipulation of the Student: An Overview of Strategy Modification

Factors Influencing Strategy Selection and Utilization

- Intellectual Aptitude and the Availability of Strategy Skills
- Personality Variables
- Cognitive Style
- Reception Preferences
- Motivation, Sex, and Prior Knowledge

Learning Strategies: General

Learning Strategies: Specific

- Comprehension Strategies
- Memory Strategies
- Problem Solving and Creativity

Manipulation of the Educational Environment Versus Manipulation of the Student

Let us begin with the following quote of unknown origin: "Give a man a fish and you feed him for a day. Teach a man how to fish and you feed him for a lifetime." Revising it we arrive at a somewhat updated version: "Give a man some cleaned, cooked fish, and you feed him for a day. Teach a man the art of acquiring, cleaning, storing, and cooking fish and you feed him for a lifetime."

If in the above quote we substitute "knowledge" for "fish," we now have a statement of some relevance to education. Attempts at improving instruction by manipulating the educational environment (that is, improving teaching) appear to be roughly analogous to attempts at "giving a man some cleaned, cooked fish," that is, providing knowledge in its most immediately consumable form. Conversely, attempts at manipulating the student (that is, improving learning strategies) are analogous to "teaching a man the art of acquiring, cleaning, storing, and cooking fish," that is, providing skills appropriate to acquiring and using knowledge regardless of its form. As is obvious from the remaining portions of the original quote, the authors are biased toward improvement of educational effectiveness via the latter approach. The remainder of this section will deal with the shortcomings of attempts at improving teaching methods without regard to learner strategies.

Studies on improving teaching have dealt with a variety of aspects of the educational environment. The effects of manipulating mode of presentation (lecture, discussion, movie, reading, computer, etc.), activity level of the student (responses required), pacing (rate of presentation), and sequence of instruction (ordering of concepts) have been assessed in numerous studies. The first criticism of this approach stems from the general ineffectiveness of these types of manipulations. Dubin and Taveggia (1968) in an extensive review of the educational literature conclude that their "Data demonstrate clearly and unequivocally that there is no difference among truly distinctive methods of college instruction when evaluated by student performance on final examinations (p. 35)."

As an example of this apparent ineffectiveness at a more specific level, Dansereau, Evans, Wright, Long, and Actkinson (1973) and Dansereau, Evans, Actkinson, and Long (1973) reviewed the literature and conducted a series of experiments on the effect of instructional sequencing on comprehension and retention. In general, the previous results on sequencing have not been very encouraging. Experiments comparing random versus logical sequences of programmed learning material have resulted in marginal or no effects on performance variables. The Dansereau, et al. studies corrected a number of the difficulties observed in previous studies and still found only marginal effects due to sequence. In these experiments, as well as previous ones, there have been substantial differences in performance between individuals that are unrelated to treatment conditions. This state of affairs would lead one to conclude that the aptitudes and/or strategies available to an individual may be prime contributors to performance differences.

A number of researchers have hypothesized that individuals with different aptitudes would benefit from different teaching methods. In order to assess the feasibility of this hypothesis, Bracht (1970) has exhaustively reviewed studies designed to investigate aptitude-treatment interactions. Based on this review he has concluded that there is virtually no solid evidence for the existence of such interactions. Apparently, tailoring teaching methods to individuals varying in aptitude will not substantially improve educational effectiveness as it is typically measured.

Besides being marginally effective, an exclusive focus on improving teaching methods may lead to inadvertent reinforcement of inappropriate and non-transferable learning strategies. Many approaches to teaching implicitly encourage rote memorization, a strategy which leads to the storage of information in a non-integrated fashion. In effect, knowledge acquired through rote repetition does not get meaningfully related to other stored material. This severely limits the facility with which such information can be retrieved at a later date. Such a strategy, although perhaps useful in our present educational environments, is very maladaptive in many job situations where understanding is far more important than mere storage. Although the limitations of rote memorization have been emphasized, the same arguments probably apply to a large number of other strategies developed by students to cope with a teaching-oriented education.

In not stressing learning strategies, educators, in essence, discourage students from developing and exploring new strategies, and in so doing limit the students' awareness of his cognitive capabilities. These factors would not only limit an individual's participation in a situation requiring new learning strategies, but if the present strategies an individual has adopted do not match his cognitive capabilities, the emotional toll may be devastating. Most of us know individuals who spend inordinate amounts of time memorizing college or high school materials and are still barely "getting by." Such an individual's personal, intellectual, and social development must certainly suffer from the pressures created by his use of a relatively inefficient (although ultimately perhaps effective) learning strategy.

In summary, exclusive emphasis on teaching methods may lead to ineffective instructional manipulations, may force students to develop non-transferable and inefficient strategies, may limit a student's cognitive awareness and performance, and may, consequently, extract a large emotional toll. The answer to this situation is clear, educators and researchers should be re-directing at

least some of their efforts to the development and training of appropriate learning strategy skills. In the next section we will provide a brief overview of this latter approach to educational improvement.

Manipulation of the Student: An Overview of Strategy Modification

The focus on teaching, in particular attempts at improving the presentation of materials, stems directly from the behavioristic (stimulus-response) influences that pervaded psychology up until the mid-1950's. Behaviorism has traditionally ignored the organism and has concentrated on establishing relationships between stimuli presented and subsequent responses observed. To most behaviorists the organism is an inscrutable "black box" which is not amenable to scientific investigation. In the 1950's there was an increasing emphasis on more complex behaviors such as problem solving and language processing. The failures of behaviorism to adequately deal with these "higher order" activities stimulated the growth of a new school of thought: Cognitive psychology. The cognitive psychologist, unlike the behaviorist, emphasized the role of the organisms "covert" manipulations of the incoming stimuli in predicting responses. Bruner, Goodnow, and Austin (1956) developed procedures for identifying subject strategies and demonstrated that different strategies were differentially effective for a concept learning task. Newell, Simon, and Shaw (1958) effectively simulated problem solving strategies via computer. Finally, Miller, Gallanter, and Pribram (1960) analyzed and catagorized strategies used in a wide range of tasks.

Since these early efforts, the cognitive approach has replaced behaviorism as the dominant school of thought in experimental psychology. As is usually the case application lags behind basic research. Only recently have cognitive influences had a substantial impact on education. Even now there is a large amount of information available from basic cognitive studies that needs to be translated into the educational domain. As a step in this direction, this review and synthesis is an attempt to integrate information from cognitive and educational research related to learning strategies.

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Strategies, which can be defined as ways of selecting, storing, manipulating, managing, and outputting information, occur at all levels of behavior. Similar taxonomies for strategies involved in or related to learning have been devised by DiVesta (1971) and Posner (1964). In general, they have developed three categories of strategies which roughly correspond to those involved in memorization, comprehension, and problem solving. For the purposes of this review we will maintain a similar categorization and will discuss the corresponding strategies separately.

It should be obvious that the types of strategies used by an individual and their resulting effectiveness will be determined, at least to some degree, by intellectual and personality characteristics. Consequently, the first portion of this report will deal with factors influencing strategy selection and utilization, followed by a discussion of general and specific performance effective strategies falling under the previously mentioned taxonomic categories.

At various points in the review and synthesis, attempts will be made to delineate potential strategy training procedures. At least two general options are available along this line, individuals can be trained intensively in strategies in a separate course (speed reading and learning skills courses would be examples of this approach) or they can be trained in strategies in the context of regularly occurring content courses via teaching manipulations. Because the skills acquired in speed reading and study courses often do not transfer to other situations, the second alternative is perhaps more attractive. However, utilizing recently developed techniques of behavior modification, separate courses may be structured to facilitate the transfer of acquired skills. This latter possibility also deserves exploration.

Factors Influencing Strategy Selection and Utilization

The purpose of this section is to discuss various characteristics of the individual that would influence him to choose or develop one learning strategy over another. In addition, the discussions will also focus on the characteristics that would influence the subsequent effectiveness of the selected strategies. Toward this end, the following potential factors will be considered separately: intellectual aptitude and the availability of strategy skills, personality variables, cognitive style, reception preferences, motivation, sex, and prior knowledge.

Intellectual Aptitude and the Availability of Strategy Skills.

Not surprisingly, IQ has been found to be a dramatic individual difference variable in most psychological and educational research and should obviously be taken into account in the development and training of learning strategies. To date, such work has been limited only to showing the existence of gross performance differences related to IQ, a limitation which surely needs to be remedied in future studies.

A second aptitude factor which is somewhat independent of IQ has been termed conceptual or integrative complexity. This has been defined as: "The extent to which dimensional units of information can be interrelated in different ways in order to generate new and discrepant perspectives about stimuli (Schroder, Driver, and Streufert, 1967, p. 25)." This aptitude or capacity has been measured by a variety of techniques. For example, subjects are asked to complete a passage on some academic topic. Expert raters then analyze the subject's output for the following type of evidence: inability to generate conflict or diversity, inability to view a situation from another person's point of view and see it in relation to one's own, inability to generate alternate perceptions and outcomes, tendency to seek structure, avoid delay, to close fast, etc. Persons with the above tendencies are rated "concrete" or "simple," persons with opposite tendencies are rated "abstract" or "complex."

Schroder, Driver, and Streufert (1967) have also measured conceptual complexity in a multidimensional scaling task. In this situation a multivariate technique is used to abstract a subject's conceptual space from his similarity judgments of all possible pairs of stimuli (for example, semantic concepts). The more a conceptual space contains dimensions of information that are not objectively or directly given by the situation, the more "abstract" or "complex" the individual. The "concrete" or "simple" person is considered to be more "stimulus bound." Also, according to the above authors, more balanced use of dimensions indicates a more "abstract" individual.

In tactical simulation games, conceptually complex people apparently develop higher level strategies than simple persons no matter what the level of environmental complexity (Streufert, Clardy, Driver, Karlins, Schroder and Suedfeld, 1965; and Driver, 1962).

Claunch (1964) compared the examination performance of "concrete" (simple) and "abstract" (complex) students (holding Scholastic Aptitude Test scores constant) in an introductory course on personality. On objective questions, "abstract" and "concrete" individuals scored equally well, while on essay questions, "abstract" persons performed at a significantly higher level.

Along a similar line, Suedfeld and Hagen (1966) showed that high conceptual level subjects were better than conceptually simple subjects at solving complex verbal problems, but not at solving simple ones.

"Complex" and "simple" individuals were asked to identify an indistinct or unstructured stimulus pattern and their pre-decision information processes were assessed. Structurally complex Ss generated more alternative responses and made greater differentiating, encoding, and inferring responses (Sieber and Lanzetta, 1964). Uncertainty and mediation training increased this information seeking behavior of structurally simple Ss to the level of structurally complex Ss (Sieber and Lanzetta, 1966; Saloman, 1968). Analogous training procedures have also been worked out for academic environments (Sieber, 1969).

Conceptual complexity, which exhibits correlations ranging from .12 to .50 with IQ, appears to be a potentially potent factor in determining the types of strategies which can effectively be used by an individual. Obviously, learning methods requiring rapid integration of a diverse set of materials would be extremely difficult for a conceptually "simple" individual to employ. Conversely, "complex" students may become bored with simple strategies. Clearly, this variable needs to be considered in developing strategy training programs. The results of Sieber and Lanzetta (1966) and Salomon (1968) suggest that such programs might usefully include attempts at actually manipulating conceptual complexity.

Training students to construct their own performance-effective strategies is probably even more important than instilling specific techniques or methods. In either case, a student's strategy skills will be of critical importance. Even if trained in specific strategies, the student must know when such techniques can be appropriately used.

The Structure of Intellect model (Guilford and Hoepfner, 1971) provides a good framework for discussing strategy skills. In this model, five intellectual "operations" have been identified by factor analysis of a large variety of paper and pencil tasks. These operations and their corresponding descriptions are as follows:

(a) Cognition - Immediate discovery, awareness, rediscovery, or recognition of information in its various forms, comprehension or understanding.

(b) Memory - Fixation of newly gained information in storage.

(c) Divergent production - Generation of logical alternatives from given information, where emphasis is upon variety and quantity.

(d) Convergent production - Generation of logical conclusions from given information, where emphasis is upon achieving unique or conventionally best outcomes.

(e) Evaluation - Comparisons of items of information in terms of variables and making judgments concerning criterion satisfaction.

Based on their descriptions, these intellectual operations can be associated with the various processes generally required of a strategic learner facing a new task situation:

1. Task perception - The learner must identify and store the task requirements, constraints, etc. (primarily cognition and memory).

2. Strategy generation - The learner must recall or construct alternative strategies that presumably would satisfy the task requirements (primarily divergent production).

3. Strategy selection - The learner must select a strategy for implementation (primarily evaluation and convergent production).

4. Strategy implementation - The learner must attempt to complete the task using the selected strategy (potentially could involve all of the Structure of Intellect operations).

5. Strategy evaluation - The learner may evaluate his progress with the selected strategy and persist or reselect depending on the outcome of this evaluation (primarily evaluation).

From the above analysis, it seems reasonable to assume that the Structure of Intellect operations generally correspond to the basic skill components required for the development and implementation of learning strategies. Prior empirical work has shown that ability to perform the Structure of Intellect operations strongly relates to achievement in ninth grade math (Guilford, Hoepfner, and Peterson, 1965; and Guilford and Hoepfner, 1971), tenth grade geometry (Caldwell, Schroder, Michael, and Meyers, 1970), advanced calculus (Hills, 1957), and concept learning (Dunham, Guilford and Hoepfner, 1968).

The Structure of Intellect model probably should be used as a device for diagnosing strategy skill deficiencies. Based on these diagnoses specific training can be provided. It should be noted, however, that an individual with appropriate prerequisite skills is not necessarily equipped to combine these skills in an effective fashion. This individual will most likely have to be further trained to efficiently employ his skills during strategy development and utilization.

Personality Variables.

The personality of a student will undoubtedly influence which learning strategies he selects and how effectively he implements these strategies. Perhaps the best way to illustrate these potential effects is to provide a few examples relating personality to performance on academic - like tasks.

Rokeach (1960) implied that highly dogmatic learners would presumably reject new belief systems because of the threat such individuals associate with beliefs which differ from their existing cognitive systems. They, more than others, would probably avoid discrepant or novel information. On the other hand, low dogmatic learners would presumably experience no such threat and would, accordingly, be open to novel information. Experimentation on this issue has shown that high dogmatics make more errors than low dogmatics in learning "belief incongruent" associates (for example, ball-square) but excell in the acquisition of "belief congruent" pairs such as ball-round (Adams and Vidulich, 1962). Along similar lines, Kleck and Wheaton (1967) found that high dogmatics recalled less information which disagreed with their existing beliefs than low dogmatics.

A related variable focuses on an individual's view of ambiguous information. Budner (1962) defined intolerance of ambiguity as a tendency to view ambiguous situations as threatening and tolerance of ambiguity as a tendency to view such situations as desirable. Feather (1964) found that the higher the intolerance for ambiguity the stronger the tendency to judge congruent arguments as correct even when those arguments were invalid.

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Dogmatism and tolerance of ambiguity would primarily influence strategy selection in tasks involving the manipulation of ambiguous or belief discrepant information, while a third personality variable, internal-external control of reinforcement, would appear to have a more pervasive impact.

The concept of Internal versus External control of reinforcement, introduced by Rotter (1966), refers to the degree of control the person judges that he has over his environment. The person at the "internal" end of the continuum perceives outcomes to be a consequence of his own actions. The person at the "external" pole believes that outcomes are due to fate, luck and powerful others, and therefore, are beyond his personal control. "Internals" more actively seek information relevant to problem solving than "externals" (Davis and Phares, 1967). "Internals" tend to retain more information when this information is relevant to personal goals (Seeman, 1963, Seeman and Evans, 1962). And "Internals" tend to better utilize information that has been equivalently acquired and retained by internals and externals (Phares, 1968). Julian and Katz (1968) using a synonym/antonym word-pair identification task showed that "internals" spend more time on difficult items than on easy ones, while externals' decision times are not related to item difficulty.

In an extensive review, Coleman et al. (1966) found that sense of control over the environment was the best single predictor of Black students' academic achievement. It is interesting to note in this regard that Internal-External control is virtually unrelated to IQ (Hersch and Scheibe, 1967; Rotter, 1966). Because of its apparent impact on strategies and academic success this variable will be explored further in the present research program.

Cognitive Styles.

Cognitive styles, in many cases, appear to mediate between personality characteristics and aptitudes on one hand, and concrete strategies on the other. Cognitive styles have been defined by Witkin (1973) as: "characteristic modes of functioning that we show

throughout our perceptual and intellectual activities in a highly consistent and pervasive way (p. 2)," and by Kagan, Moss, and Sigel (1963) as: "stable individual preferences in the mode of perceptual organization and conceptual categorization of the external environment (p. 74)." As can be seen from the above definitions, cognitive styles act more or less as meta-strategies, and as such create definite boundaries on the types of specific strategies available or potentially available to individuals. Examples of specific cognitive styles and their relationship to educationally relevant variables will be presented next.

Category width. A number of studies (Gardner, 1953; Bruner, Goodnow, and Austin, 1956) have demonstrated that individuals tend to use relatively constant category widths in the classification of objects and events. Pettigrew (1958) developed a Category Width Scale which has now been related to a large number of other variables. Category Width has been positively correlated with breadth of stimulus generalization (Wallach and Caron, 1959), and negatively related to the recall of human faces in an incidental learning task (Messick and Damarin, 1964). High scorers (large category width) make more accurate perceptual judgments under normal conditions but not under distracting conditions (Bieri, 1969).

Cognitive control. Klein (1954) characterized subjects who were susceptible to color-word interference on the Stroop (1935) test as employing a "constricted" mode of cognitive control and those less susceptible as employing a "flexible" mode of control. Lazarus, Baker, Broverman and Meyer (1957) found that under high relative to low incentive conditions that high interference subjects ("constricted" control) made more errors than "flexible" Ss in transcribing tape recorded material.

Descriptive-analytic versus inferential-categorical versus relational-contextual. Kagan, Moss, and Sigel (1963) have identified three style categories based on the subjects' grouping of common pictorial stimuli. In using a descriptive-analytic style the individual tends

to prefer to split these environmental stimuli into discrete entities and to respond to them as separate units. When the analytic individual is required to group stimuli for purposes of categorization, he tends to base his groupings on objective attributes shared by all of the stimuli. The inferential-categorical style is typified by a grouping of the stimuli which are categorized together. The relational-contextual response is based on a preference on the subject toward categorizing stimuli on the basis of functional or thematic relationships which may occur among these objects.

Generally these last two categories are combined to form a "non-analytic" category. Thus producing a bi-categorical system, analytic style versus nonanalytic style. Sigel (1967) has constructed a paper and pencil test for tapping these two styles.

Subjects who have been found to be analytic appear to attend to more factual detail in concept acquisition (Kagan, et al. (1963), are superior to nonanalytics in learning concepts based on objective similarity of detail among visual stimuli (Lee, Kagan, and Rabson, 1963), and score higher on performance tests than verbal tests (Kagan, Rosman, Day, Albert, and Phillips, 1964). Conversely, nonanalytics score better on verbal tests than performance tests; learn functional relationships better than analytics; and tend to be more impulsive than analytics on tests of cognitive control (Kagan et al., 1963; Kagan et al., 1964). There does not, however, appear to be a significant difference between these two style categories in terms of IQ.

Beller (1967) has demonstrated that a specific teaching method can be designed to facilitate the learning of children in associating words with objects when the cognitive styles (analytic versus nonanalytic) of these children are identified and used to assign the children to teaching methods which are consonant with their stylistic preferences.

On the other side of the coin, Scott and Sigel (1965) showed that inquiry versus expository teaching methods used in grades 4, 5, and 6 actually influenced responses on the Sigel Cognitive Style Test (1967), thus indicating that the analytic-nonanalytic styles are somewhat modifiable.

Field dependence - field independence. The notion of field dependence and field independence was originally developed by Witkin and his colleagues (Witkin, Dyk, Faterson, Goodenough and Karp, 1962; Witkin, Lewis, Hertzman, Machover, Meissmer, and Wapner, 1954). The Rod and Frame Test (RFT), in which the subject is required to directly or indirectly adjust a movable rod to the true vertical position while the rod itself is located in a separately tilted frame, and the Embedded Figures Test (EFT), in which the individual must detect simple geometrical figures contained within much more complex figures, have been used to assess field dependence. The more difficulty an individual has on the above two tasks the greater is his field dependence. Witkin and his colleagues (1967) have shown the invariance of the EFT and RFT scores under a variety of natural (for example, age, marriage, divorce) and experimental (for example, drugs, ECS, hypnosis) conditions.

Kennedy (1972) found that field independence (FI) was related to success in aviation training for both pilots and non-pilots. These findings are consistent with a number of other studies that reported superior performance by field independents on various pilot simulating, pilot related, or pilot selective tasks (Benfari and Vitale, 1965; Thornton, et al., 1968; Barrett and Thornton, 1968; Crutchfield, et al., 1958). In addition, engineers have been found to be more FI than a general college sample (Barrett and Thornton, 1967), while students majoring in liberal arts are more field dependent (FD) than those majoring in physics, math, and chemistry (DeRussey and Futch, 1971). Finally, it also appears that children with learning difficulties generally tend to be field dependent (Keogh and Donlon, 1972; Bruininks, 1969; Stuart, 1967).

A few attempts have been made to match these styles with teaching method. Hester and Tagatz (1971) used a measure highly correlated with the EFT to assess analytic (FI) and global (FD) cognitive styles. They then instructed their Ss in two concept attainment strategies: "Commonality" (determining attributes common to correct instances) and "Conservative" (comparing negative and positive instances to find differences). Ss displaying analytic (FI) styles apparently could use either strategy effectively, while Ss displaying a global (FD) style were able to use the commonality strategy but not the conservative strategy. In another study, Grieve and Davis (1971) tested Analytic (FI) and Global (FD) subjects after 11 hours of geography using two methods of instruction (expository and discovery). They found Analytic (FI) Ss did generally better than Globals (FD) and that there was no aptitude treatment interaction.

Cognitive styles: Implications. The examples presented above provide clear evidence as to the relatively strong relationship between cognitive style variables and academic-like performance. These styles or meta-strategies deserve further consideration in the tailoring of instructional methods to individuals. In this regard, style-treatment interactions should be systematically assessed.

The apparent academic superiority of some styles over others would suggest that explorations of training procedures should be undertaken. Most researchers have assumed styles are relatively fixed: however, there have been only a few scattered attempts at modifying styles through training. Perhaps teaching individuals specific concrete strategies that are incompatible with their styles would ultimately serve to alter these meta-strategies.

Finally, if styles did prove to be substantially unaffected by modification procedures, then strategy training programs would have to be concerned with matching strategies to styles.

Reception Preferences.

At a somewhat more specific level than cognitive styles, individuals have preferences for receiving information in certain ways. As with styles, these preferences should influence the strategies available to a student and the effectiveness with which he applies them. Depending on their potency, these preferences will either limit which strategies can be taught to an individual or will themselves be modified by strategy training procedures.

Learning style preferences. Hartnett (1973) assessed four dimensions of learning style preference in 2,175 Ss. These dimensions were:

(a) Preference for regular classwork versus independent study.

(b) Preference for objective versus essay examinations.

(c) Preference for lectures versus discussion.

(d) Like versus dislike of doing individual research.

As a result of this assessment study Hartnett found the following:

On entering college, students generally preferred: regular classwork, objective exams, discussions, and were equally divided on attitude toward individual research.

"Bright" entering students (as measured by Scholastic Aptitude Test scores and high school grade point averages) preferred: regular classwork, objective exams, lectures, and individual research.

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During the first two years of college trends in preference generally were: from assigned to independent study, objective exams to essay exams, discussion to lectures, and toward more individual research.

However, though there was a steady move toward preferences for less traditional styles during the first two years of college, it appeared to be the less able students whose learning style preferences were drifting in this direction. Although there were relationships between preferences and academic performances, it is not clear whether learning style preferences are a cause or an effect of course grades. Obviously, further research on this issue is needed.

If learning style preference proves to be a viable educational variable then matching of instruction to preference would probably be beneficial. If such matching is impossible or ineffective, perhaps the teaching of effective strategies for dealing with non-preferred instructional methods would enhance the achievement of "poor" students.

Educational set. Closely related to learning style preference is a variable that has been labeled educational set by Siegel and Siegel (1965). The two extremes of educational set can be described as follows:

A factually set learner is one who, by definition, is predisposed to learn factual content. He adds units of information to his cognitive structure without being driven to interrelate these elements into any conceptual whole. For such a learner, a fact has an integrity of its own.

A conceptually set learner is one who, by definition, rejects factual acquisition except as units of information that are clustered and interrelated. He prefers to learn concepts and principles. When confronted by a bit of factual information he either dismisses it as "unimportant" or subsumes it under a broader conceptual framework.

Siegel and Siegel (1965) measured educational set by a force choiced inventory (Educational Set Scale) which required preference judgments. They showed that conceptually set learners exhibited higher performance on both conceptual and factual aspects of a final exam in a televised college course. In addition, Sanders and Tzeng (1971) found some evidence that preference for conceptual versus rote learning was related to actual performance on concept learning and rote learning tests in the predicted directions.

Based on these findings and intuitive grounds it seems reasonable to attempt to alter educational set in a conceptual direction. However, it is possible that by the time a student reaches college age, his educational set is relatively fixed and resistant to change. If this is the case, the present studies suggest the wisdom of arranging for congruence between the student's set and the educational goals imposed upon him.

Media preferences and effects. Instructional information can be presented pictorially, verbally, auditorily, live, taped, or in some exotic combination of the above. Preferences for various types of media will potentially influence strategy utilization in ways analogous to cognitive style, learning style preferences and educational set. The actual effectiveness of various media in conveying information may reflect preference or the differential availability of effective acquisition strategies for different modes of presentation. If the latter case is correct, then strategy training will have to be media specific and should probably focus on the less effective types of media.

The hypothesis that adults generally have preferences for visual information is supported by Lordahl's (1961) finding that in a concept discrimination task subjects were more likely to attend to visual than to auditory stimuli. Also, Stevenson and Siegel (1969) found that as children get older, they pay increasing attention to visual information in film presentations and less attention to the auditory information.

James (1962) asked 503 basic airmen to express preferences for taking lesson by reading or by lecture (a no preference option was permitted). There were no performance differences associated with preference but for the total sample learning by reading was superior to lecture (.05 level). Preference was unrelated to ability, but the superiority of reading was greater for high-ability airmen.

In accord with the above study, at the high school level and beyond, research results usually favor reading over listening (Belcastro, 1966; Beighley, 1952; Cody, 1962). King (1968) and King and Madill (1968) found that with college students reading and listening were about equally effective for retention of factual material, but that reading was superior for the comprehension of the "gist" or "theme." Research with nonprose verbal materials support the idea that visual presentation is increasingly advantageous for more difficult material (Schultz and Kasschau, 1966; Van Mondfrans and Travers, 1964).

Combined auditory-visual presentation of connected prose either shows no advantage over visual presentation or actually constitutes an interference (Mowbray, 1953), particularly if the materials are easy.

In exploring the pictorial-verbal aspect of media, most researchers find that ideas represented pictorially are more easily learned than ideas represented by single words (Jenkins, Neale, and Deno, 1967; Lieberman and Culpepper, 1965). Rohwer, Lynch, Levin, and Suzuki (1967) found that memory for paired associates was enhanced when pictures of them showed action (as opposed to still pictures).

With more educationally relevant material the results are not nearly so clear cut. Parsons and Frase (1968) reported that college students learn electricity principles just as well from verbal presentations as they do from graphic presentations. Dworken and Holden (1959) found no differences in the effectiveness of lectures and filmstrips for teaching atomic bonding to graduate engineers. In addition, Eyestone (1966) found no differences between bulletins, films, and lectures in teaching 4-H club information.

On the other hand, Frederick (1969) found that students learned grammatical principles better from symbolic representations (tree diagrams of syntactical representations) than from verbal statements. Dansereau, Evans, Long, and Actkinson (1973) found that college students learned basic physics concepts and oscilloscope operating procedures slightly better with a predominately pictorial rather than a predominately verbal presentation.

The data on verbal versus pictorial presentation is indeed inconclusive. In addition to emphasizing individual differences and preferences, attention should be focused on equating familiarity with the codes and grammars of the media under examination. Our present educational systems provide extensive training in verbal skills, but little or no training in pictorial skills, thus biasing the above results in favor of verbal presentation. Training on pictorial skills may in fact lead to marked improvement in learning from pictorial presentations. Salomon (1972) has suggested that training Ss on pictorial conventions such as slow motion, zooming, object rotation, etc. could aid in processing from pictorial presentations and could improve a student's imagery capability.

With regard to combining verbal and pictorial presentations, Travers (1966, 1967) has reviewed a series of experiments which suggest that combined presentations are often less beneficial than presentations through single channels. He believes that combined presentations require rapid alterations of attention and may cause overloading of the separate channels.

Motivation, Sex, and Prior Knowledge.

Although beyond the scope of this review, it is worth noting that there are a number of other individual difference variables that would potentially influence the selection and utilization of particular learning strategies. Any comprehensive attempt at identifying and training educationally relevant strategies would have to take into account the motivation, sex, and prior knowledge of the students involved since each of these variables has proven to be significantly related to outcomes in learning-oriented experimentation.

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Learning Strategies: General

In the previous section we discussed a number of variables that could potentially influence learning strategy development and utilization. It is now time to focus on actual strategies and their relationship to academic or academic-like performance. In this section we will take a brief look at grossly defined study strategies and behaviors. These learning techniques are primarily measured by responses to generally stated questionnaire items and consequently suffer from the lack of actual behavioral referents. However, the problems involved in tapping strategies in this way are probably overshadowed by the economy and efficiency associated with the questionnaire approach.

In addition to looking at the relationship between responses to questionnaire items and academic performance, we will also discuss some of the attempts made to modify study behaviors.

Surveys of Study Strategies and Behavior.

The four major questionnaires treated in the research literature will be presented separately.

Brown and Holtzman survey of study habits and attitudes (SSHA). Brown and Holtzman (1953, 1966) developed, and revised a questionnaire to survey students' study habits, as well as their attitudes and motivation toward academic work. In its current form there are two major subscales. The Study Habits subscale contains items dealing with actual behavioral tendencies associated with effective academic work, such as promptness in dealing with assignments, ability to deal with distractions and use of effective study procedures. The Study Attitude subscale, on the other hand, focuses more on academic opinions and beliefs and contains items inquiring about the students' attitudes toward teachers, teaching methods, and various educational objectives and requirements.

The relationships found between total scores on the Survey of Study Habits and Attitudes (SSHA) and the Scholastic Aptitude Test (SAT) are typically very weak (correlations of about .05), thus indicating that reported study habits and attitudes are independent of intellectual ability (Brown and Holtzman, 1966).

On the basis of the data obtained from several different college populations, Brown and Holtzman (1966) reported that the average correlation between the SSHA and grade point average was found to be .36. Using a high school population, Holtzman and Brown (1968) found the correlations to be somewhat higher, averaging approximately .49. Reporting lower, but nonetheless significant correlations between SSHA and grade point average, Garcia and Whigham (1958) found that the correlations increased slightly when the SSHA was administered after the students had some college experience. Thus, in comparison to correlation of .24 when the SSHA was administered prior to entrance into college, a correlation of .32 was obtained after the students had experienced between one to two quarters of college.

Obviously the relationship between study habits and attitudes and ultimate academic achievement may vary depending upon the nature of the courses in question. Brown and Dubois (1964) obtained significant correlations between SSHA scores and grades with engineering students, but failed to obtain significance for science and humanities students.

In comparison to SSHA scores, SAT measures turn out to be better predictions of grade point average. However, a multiple correlation involving SSHA and aptitude scores is a better predictor of grades than either of the two measures separately.

Goldfried and D'Zurilla (1973) correlated scores on the SSHA with peer and self ratings of effective behavior in various types of situations related to academic life (for example, relationships with instructors regarding academic matters, selecting a major and a career). SSHA and peer ratings correlated .45, while SSHA and self ratings correlated .53.

Biggs' Study Behavior Questionnaire (SBQ). Factor analysis of the SBQ (Biggs, 1970a) resulted in the following six factors: study organization, tolerance of ambiguity, cognitive simplicity, capacity for intrinsic motivation, dogmatism, and independence of study behavior. This questionnaire is composed of factors reflecting both study skills and cognitive styles.

Biggs (1970b) reported low, but significant correlations between SBQ factors and standard personality tests. He concludes that the correlations, although low, confirmed, and in some cases augmented, the meanings attributed to the factors in the previous study.

Biggs (1970a) administered his questionnaire to 314 students entering in either the Arts or the Sciences at a university in Melbourne, Australia. He found that Arts students tended to be more organized in their approach to study than Science students, but that organization had no direct relationships to performance. Significant relations found between SBQ factors and performance belonged to the cognitive style domain (cognitive simplicity, ambiguity, dogmatism, and independence) rather than the easily trainable skills-habit domain. Biggs concludes that attempts to alter study behavior should be directed towards a deeper level of operating than is aimed at by the usual study skills program (for example, Morgan and Deese, 1957).

Goldman and Warren Study Strategy Questionnaire (SSQ). Goldman and Warren (1973) developed a 64 item questionnaire from students' responses to the question, "What study strategies do you use?" Factor analysis of the responses to the questionnaire resulted in seven subscales: clerical diligence, academic savy, mnemonics, planfulness, formal thinking, note taking, and transformation and application.

Goldman and Hudson (1973) administered the questionnaire to 256 freshmen college students. In addition, they administered selected abilities tests from the kit of Reference Tests for Cognitive Factors (French, Ekstrom and Price, 1963). Major field groups (science versus nonscience) were found to differ

significantly in both abilities and strategies. Number facility was the best ability discriminator among major fields, while formal reasoning (logic) and transformation-application were the best strategy discriminators. It appears that the science majors excell in number facility and make more use of formal reasoning (logic), while nonscience majors make more use of transformation-application (active integration of scholastic information). When abilities are partialed out, the strategy differences between major fields become even clearer. However, when strategy measures are partialed out, the ability differences between major fields are no longer significant, thus, suggesting that strategy differences between major fields exist independently of ability differences.

In comparing high, middle, and low grade point average groups, it appeared that the groups differed on strategies but not on abilities. Planfulness and formal reasoning best discriminated among grade point average groups. Goldman and Hudson conclude that the findings support the idea that strategies may be more fundamental determinants of academic success than abilities.

Questionnaire on strategies employed in learning statistics. Goldman (1972) developed a short statistics learning strategy questionnaire based on a series of interviews with undergraduate psychology students. The questionnaire required students to indicate which of the following strategies best described their approach to statistics:

(a) Mathematical - Formal: Try to learn algebraic derivation of each statistical technique.

(b) Logical - Formal: Try to learn the underlying reasons for the technique in a verbal way.

(c) Mnemonic - Concrete: Try to learn the computational techniques by observing examples often without worrying about reasons for the technique.

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The mathematical-formal strategy was so rarely chosen that it was combined with the logical strategy group for the purposes of experimentation. Goldman (1972) compared strategy groups with respect to performance in two undergraduate classes: statistics and experimental psychology. The logical group received significantly higher grades on a number of academic criteria in both courses. Criteria included course grades, test grades, laboratory grades, and term paper grades. The strategy groups did not differ significantly on six ability measures, nor did removal of ability covariants reduce the performance differences between strategy groups. On the basis of these results, Goldman concludes that educators and researchers should seek the "most efficient" strategies for given tasks.

The above questionnaire studies have shown that strategies, delimited in this relatively economical fashion, do relate to academic performance, and in many cases, overshadow traditional ability measures. These results are particularly encouraging in light of the fact that the construction of these questionnaires has not generally been based on the strategy-oriented experimental psychology literature, nor has it led to complete coverage of potential strategy differences. The questionnaire to be created in conjunction with the present research project will hopefully be complete in both of the above regards. In addition, the present project will extend previous studies by using the questionnaire as a diagnostic tool upon which subsequent training programs can be based.

Study skills training. Although many educators and researchers express the desirability of study skills training courses, very few evaluations of the effectiveness of such courses have been undertaken. Further, the content of evaluated courses is usually restricted to standard study techniques such as the SQ 3R Method (Robinson, 1946).

Briggs, Tosig, and Norley(1971) found that study skill training led to significantly higher grade point averages (than a no-treatment control group) on the part of a group of "high risk" college students. Brown, Webe, Zunser, and Haslam (1971) and Haslam and Brown (1968) found that Brown and Holtzman Survey of Study Habits and Attitudes scores increased as a function of participation in a study skills training program.

Obviously further effort needs to be directed toward the development and assessment of study strategy training programs. In particular, these programs should be expanded to include effective strategies identified in the recent memory, comprehension, and problem solving literature. Further, the strategy training necessary should be diagnosed by responses to a strategy questionnaire and specifically tailored to an individual or group. As indicated earlier, the present research program will provide a first step in this direction.

Learning Strategies: Specific

The remainder of this review will deal with strategies and strategy-related findings appearing in the areas of comprehension, memory, and problem solving and creativity. Since much of the research in these areas is "basic," there will be intermittent suggestions as to directions for future development and application.

Comprehension Strategies.

This section will provide separate coverage of the effects of organizational strategies, questions, note-taking, and reading flexibility on comprehension and retention.

Organizational strategies in comprehension. Generally, research in this area can be further subdivided into that dealing with advanced organizers, passage organization, and post organizers.

Advanced organizers - Ausubel (1960) assumes "...that cognitive structure is hierarchically organized in terms of highly inclusive concepts under which are subsumed less inclusive subconcepts and informational data." If this is true then the learning of new meaningful material ought to be facilitated by insuring that the learner has inclusive concepts which will permit him to subsume the new information under these concepts. Experimental studies by Ausubel (1960), Ausubel and Fitzgerald (1962), Ausubel and Youssef (1963, 1966), Scandura and Wells (1967), Proger, Taylor, Mann, Coulson, and Bayuks (1969), and Allen (1970) have generally confirmed these notions. Further, Frase (1969) found that a paragraph providing a "conceptual structuring" of subsequent learning material improved later recall. Similarly, Merrill and Stolurow (1966) found that presenting Ss with a summary of an imaginary science prior to learning to solve problems in it did not take increased time but increased the number of correct responses during the learning session and on the test.

These findings obviously support the desirability of including advanced organizing material in instructional units. Further, it can be inferred that students' comprehension would be improved by instructing (training) them to strongly attend to materials which provide an overview of the forthcoming material (for example, outlines, previews, topic headings, etc.).

Passage organization - Dansereau, Evans, Wright, Long, and Actkinson (1973) have extensively reviewed the effect of organization (temporal sequencing of concepts) on comprehension, retention and utilization of meaningful verbal material. Although there is substantial equivocality, there are a number of organizational factors which do appear to have a substantial impact on performance. Some of these factors have implications for student strategies as well as for the development of educational materials. The following principles of organization appear to be useful in both regards:

(a) Material should be ordered from "easy" to "hard" (Boutwell, 1971; Moore and Goldiamond, 1964).

(b) Related materials should be presented contiguously (Cofer, Bruce, and Reicher, 1966).

(c) Statements about all the attributes of the same concept should be grouped together as opposed to grouping all statements about the same attribute for each of the concept names (Schultz and DiVesta, 1972).

(d) Hierarchically related material should be presented from the top down (that is, highest level concepts first) (Newton and Hickey, 1965) and in a breadth first manner (that is, all information at one level should be presented contiguously) (Crothers, 1969).

(e) Repetitions of material should not be grouped together, but interspersed with other material (Shaughnessy, Zimmerman, and Underwood, 1972).

Since most educational material has not been optimally organized, it seems reasonable to train students to reorganize incoming information in accord with the above principles, and in accord with the students' own cognitive structure (that is, prior knowledge about the subject matter). Teaching the student these types of strategies would not only lead to benefits from improved organization in memory, but also from the students' active manipulation of the incoming information. Active student participation of this sort has been considered to be critical in effective comprehension and retention (Rothkopf, 1965, 1966).

To date, there have been no serious attempts to train these types of organizational strategies. A situation which sorely needs to be remedied.

Post organizers and reviews - Bauman and Glass (1969) obtained results suggesting that advance organizer type material may be more useful when presented after learning than before it. With regard to summary-like reviews, Gay (1971) and Ausubel and Youssef (1965) support the notion that reviews enhance comprehension and retention. Obviously students should be trained to formulate their own reviews in the form of outlines, summaries, etc., in addition to attending very strongly to summaries actually presented within the instructional material.

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The effect of questions. A principle purpose of previous research on this topic was to determine whether relatively specific questions, presented in conjunction with the instructional material, would facilitate criterion performance as compared to instruction without the questions. A second purpose was to determine the relative effects of placing the questions before the instructional material as compared with placing them after it. Bruning (1968), Rothkopf (1966), Rothkopf and Bisbicos (1967), and Frase (1968) have conducted studies on these issues. The results have been reviewed by Frase (1970) and recently criticized by Carver (1972) primarily on the grounds that such studies have not adequately controlled for learning time and strategy variables.

The findings of these studies indicate that whether questions are inserted before or after the relevant material, they nevertheless facilitate criterion performance. There is a difference in the effect of placement, however. Questions inserted prior to the passage tend to favor the acquisition of materials specifically relevant to the questions. Material not relevant to the questions is not retained as well as it is when the questions are omitted. Thus, there would appear to be a trade-off effect produced by using questions in advance of the instructional package.

Questions provided after the instructional passage have a more generally favorable effect, provided that a sequence of such passages and subsequent questions is presented. Under these circumstances, the presence of the questions facilitates the acquisition both of material relevant to the questions and of material unrelated to the questions.

These findings perhaps imply that students should be trained to formulate their own questions following the presentation of instructional material. Obviously, experimentation on this issue is needed.

Note taking. Note-taking forces the learner to be active and provides the opportunity, at least, for the learner to reorganize and elaborate incoming information. However, some students contend that taking notes during lectures hampers their listening comprehension because of the necessity for shifting back and forth between listening and writing.

Research on note-taking has been sketchy and inconclusive. A number of studies have found little or no effect due to note-taking activity. Pauk (1963) found no differences on immediate recall between subjects who took notes and those who did not. Eisner and Rohde (1959) found no differences in performance the following day between subjects who took notes during a presentation and those who took notes following the presentation. McClendon (1948) reports no significant differences in either immediate or delayed recall between those students who took notes and those who did not.

On the positive side, McHenry (1969) reports significant differences favoring note-takers on a multiple-choice test administered immediately following a study period. Peters and Harris (1970) also indicated that subjects permitted to take notes during a taped presentation or who were provided with prepared notes in topical outline form, performed significantly better on a subsequent multiple-choice test than a no-note control group whether or not time was provided for review. DiVesta and Gray (1972) found that persons instructed to take notes performed significantly better than non note-takers on both a recall task and an 8-item multiple choice test. Fisher and Harris (1973) found that a combination of taking notes and reviewing one's notes produced the most recall, while not taking notes and reviewing the lecture "mentally" produced the least recall.

Before any firm implications for education can be derived from the note-taking research, studies which vary rates of presentation and assess individual differences are necessary.

Reading flexibility. It seems reasonable to instruct students to vary their method of reading according to the nature of the text and their purposes for reading it in order to improve the efficiency of their reading. A number of studies have been aimed at assessing the degree to which students demonstrate this type of flexibility in their reading. The dependent variable most commonly used as evidence for reading flexibility is change in reading rate. The efficient reader is thought to be one who will modify his reading rate according to the difficulty of the material being read, the familiarity he has with the information being communicated, his purpose in reading, etc. Studies that have investigated the effects of these variables, however, have found surprisingly small changes in reading rate (for example, Herculane, 1961; Hill, 1964; Letson, 1958, 1959; Levin, 1968; Rankin, 1970-71; and Rankin and Hess, 1970). Although most of the studies have found some change in rate resulting from the manipulations of passage difficulty or of instructions to the readers, this change has usually been small.

There are at least two possibilities for the lack of findings in this area. First, as Rankin (1970-71) has argued, flexibility may be sufficiently subtle as to not be reflected in gross reading rates. He suggests that changes in rates within a passage should be examined. Second, since we do not usually teach flexibility in our schools, there may be only a few very insightful and motivated individuals who actually train themselves to read flexibly. This might imply that our emphasis should be on manipulating a subject's flexibility rather than merely assessing it.

In this regard, McConkie, Rayner, and Mayer (1971) and McConkie, Rayner, and Wilson (1973) varied monetary payoff conditions (the degree to which speed was important in maximizing payoff) and types of comprehension questions. They found that increasing reading speed through payoff had little effect on the amount of information retained for which a person is specifically reading, but reduces the amount of incidental information he acquires. It is possible that this payoff approach could be used fruitfully in training students to be more flexible in their comprehension processes.

Memory Strategies.

Atkinson and Shiffrin (1968) have argued for the importance of strategies in determining which information is entered into and retrieved from short and long term memory. Their term control process "refers to those processes that are not permanent features of memory, but are instead transient phenomena under the control of the subject; their appearance depends on such factors as instructional set, the experimental task, and the past history of the subject (p. 106)." The present purpose is to discuss specific examples of these control processes or memory strategies and in some cases, to extend them into the instructional domain. In this section we will consider the following topics: Encoding Processes, Organizational Strategies, Memory Management, and Retrieval Strategies.

Encoding processes. Upon receiving information an individual selects relevant portions of the information and attempts to transform these portions into maximally effective units for storage and subsequent utilization. These two processes, which may be conscious, unconscious, or both, are generally referred to as encoding processes. These processes have recently received a large amount of attention from memory researchers due to their presumed contributions to performance variance (see Melton and Martin, 1972). The two aspects of encoding: selection and transformation will be discussed separately.

Selection of information for storage. As has been pointed out, the stimulus presented is not necessarily the stimulus which functionally directs a subject's behavior. The subject actively interprets, reduces, and elaborates the incoming information. Rather than exhaustively reviewing the literature on this topic, which spans practically all of psychology, we will present a single example of selectivity, that is, changes in processing emphasis on test anticipation.

Jacoby (1973),using categorized lists, found that subjects anticipating a cued recall test were able to free recall fewer categories but more instances of each recalled category than were subjects that anticipated a free recall test. The author interprets these results as evidence that subjects preparing for a cued test spent more time studying category instances and less

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time studying category names. In effect, differential selectivity took place depending on task instructions. Cermak (1972), using a short term memory task, and Butterfield, Belmont, and Petzman (1971), using a list learning task, also found performance differences due to differences in anticipated recall requirements.

These findings support the notion that different portions of the incoming information are selected for processing based on task requirements. However, there has been no attention to individual differences in this selectivity. Studies delineating individual differences in this regard should be followed by attempts to train students to tailor their selection of portions of the incoming information to match present and future task requirements.

Transformation and elaboration of selected information. Following selection of the incoming information the subject generally elaborates and recombines the information into an efficient internal code. We will treat automatic (unconscious) and conscious attempts at these processes separately.

Hintzman (1970) and Hintzman and Block (1970) have shown that in list learning experiments subjects apparently retain surplus information without conscious intent. That is, they found that, even though not instructed to do so, Ss can accurately recall modality of presentation, position in the list of a particular item, the number of times a given word is presented, and the number of items that intervene between a given word and its repetition. This "surplus" information may in fact provide useful cues for list item recall. Further, evidence along this line is provided by two studies of individuals with outstanding memories (Curia, 1968; Hunt and Love, 1972). In both cases a substantial amount of the memory ability could be attributed to automatic "multiple encodings" of incoming information. These individuals upon hearing a word to be remembered stated that they would "automatically" see a visual representation of that word, and in some cases, even smell, taste and feel it.

Although these automatic encoding processes appear to have little relevance to education due to their apparent lack of trainability, there is some evidence to support the notion that well practiced conscious encoding processes do in fact become automatic. Bower (1970 a,b) and Kolers (1970) found that skilled readers of prose report themselves to be unaware of all encoding short of the meaning of the passage being read. Obviously, at some point in time during their development these readers must have been aware of both syntactic and semantic encoding processes. Apparently these processes have become so well practiced that they become automatic. Thus, intensive practice on some of the techniques to be discussed subsequently may in fact cause them to be used in an unconscious and perhaps parallel fashion.

With regard to conscious transformation and elaboration of incoming information, DeGroot (1965) studied the ability of the master chess player to reproduce a complex chess position after a 5 second exposure. One interesting finding was that the chess masters paused several seconds after being exposed to the stimulus before starting to recall. Less skilled players began to reproduce the board immediately, before losing the little they could retain. The same observation was made more formally by Reicher and Haller (1971) who found that differences between abilities in sight reading music only emerge if there was a delay between input and recall. It has been hypothesized that during the time interval between input and recall, the higher ability individual is recoding (transforming) the presented information into higher order meaningful units that are compatible with information he has previously stored. This hypothesis would be analogous to the process of transforming binary digits into an octal code in order to enhance short term memory (Miller, 1956). Further information on this process will be presented in subsequent paragraphs and in the section on Organizational Strategies.

Recent research has attempted to assess and manipulate these transformation and elaboration strategies that take place between input and recall. Mnemonic devices, in particular, have received a great deal of emphasis. In general mnemonic strategies involve embellishing or elaborating the material to be learned into meaningful terms and then associating items to each other or a previously learned set of peg words or images. The following are some examples of mnemonic techniques:

(a) Visualization - For example, in trying to associate a face to a name we may visualize a Mr. Carpenter as hammering that long spiked nose of his into a wall.

(b) First letter - For example, in order to remember the ordering of the 12 cranial nerves many of us have learned the phrase "On old Olympus' towering top, a fat-assed German vaults and hops." The first letter of each word is also the first letter of one of the major cranial nerves.

(c) Peg word - for example, a person has previously learned a serial list such as "one is a bun, two is a shoe, three is a tree...," as a new word comes in it is visually associated with the corresponding peg word.

(d) Narative chaining - integration of each word to be learned sequentially into a story.

(e) Method of loci - for example, mentally placing items in various distinct locations in your home.

Many studies have shown that these techniques are dramatically more effective than rote rehearsal in learning serial lists and paired associates (Groninger, 1971; Nelson and Archer, 1972; Bower and Reitman, 1972; Santa, Ruskin, and Yio, 1973; Clark and Bower, 1969; Earhard, 1967,a;Wood, 1967). Clearly, as Bower (1973) concludes, "Our schools should teach memory skills, just as they teach the skills of reading and writing (p. 70)."

One concept that underlies many of the mnemonic techniques is that of visual imagery. The importance of imagery in learning serial lists, paired associates, sentences, and prose passages has been discussed at length by Paivio (1969, 1971).

Extending Paivio's analysis, we find that the research on imagery and cerebral hemispheric specialization has provided substantial evidence for the following hypotheses:

Encouraging subjects to create mental pictures of verbally presented material greatly enhances retention of that material (Bower, 1970a; Paivio, 1969; Koser and Natkin, 1972).

Some types of material are more amenable to imagery than others. In particular, retention of abstract material is not strongly enhanced by imagery instructions (Paivio, 1969).

A relatively slow rate of presentation is generally necessary for the formation of images (Weber and Castleman, 1970).

There are individual differences in the ability to form mental images (DiVesta and Ross, 1971; Ernst and Paivio, 1971; Paivio and Ernst, 1971). Presumably this ability can be enhanced through training (Brinkman, 1968).

Visual imagery involves a memory system (perhaps localized in the right cerebral hemisphere) that is separate from that involved in storing strictly verbal material (localized in the left cerebral hemisphere) (Paivio, 1971; Seamon and Gazzaniga, 1973).

The imagery and verbal memory systems serve to supplement one another (Paivio, 1971).

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Presenting visual information actually inhibits the formation of visual images (Brooks, 1968). Apparently visual imagery involves the visual perception system and is thus disrupted by incoming visual information.

Generally our educational techniques have not capitalized on the above findings. We usually require students to rapidly process abstract verbal material with no instructions to form images. Even when we do present concrete information we generally present it visually via slides, films, etc.

It seems that the effectiveness of the instructional experience could be vastly improved by presenting at least some course material in the form of slowly presented, vivid, concrete, verbal descriptions. These descriptions should be presented auditorialy to students who are instructed to close their eyes and vividly picture the information described. Information thus presented would be supplemented by material arriving through normal instructional channels (reading, lecture, etc.).

This approach has the following potential advantages:

(a) Material presented in an imagery evoking fashion should be more efficiently retained.

(b) This imaged material will form memory "landmarks" that may aid in the storage and retrieval of normally presented information.

(c) Experience with imagery evoking material may improve a student's imagery capabilities.

(d) The easy, relaxed atmosphere associated with the imagery evoking presentation may be an enjoyable change of pace for the students.

In addition to doing research and development on the imagery evoking presentation approach, it also appears reasonable to develop an effective imagery training program, per se.

Organizational strategies in memory. This topic area is intimately related to encoding, but has usually been treated somewhat separately in the research literature. In particular, organization implies the grouping and relating of incoming material. Stimulus materials can be grouped (classified, categorized) together on the basis of common properties, and such classes can be related to one another in multiple ways.

Organizational strategies have been observed and studied with stimulus materials varying from serial lists of unrelated symbols to categorized lists to hierarchically related material. With simple serial lists, a fundamental strategy is to segment the list into several smaller chunks or groups. A number of studies have shown that groups of 3 or 4 symbols are preferred and that retention is improved when lists are segmented in this fashion (Wickelgren, 1964; Severin and Rigby, 1963; McLean and Gregg, 1967).

In free recall of word lists subjects tend to group or categorize list words into semantic units or clusters (Bousfield, Puff, and Cowan, 1964). Further, Tulving (1962) has developed a measure of Subjective Organization (SO) which reflects the consistency with which items are recalled in the same sequence from one free recall trial to the next. There is sufficient evidence now that SO and free recall performance are functionally related (for example, Mayhew, 1967). In addition, a series of experiments by Earhard have shown that Ss who are classified as high subjective organizers according to their free recall behavior patterns perform better than do Ss who are classified as low subjective organizers, under a variety of other task conditions, specifically, serial recall (Earhard, 1967 a,b), and paired associate learning (Earhard and Endicott, 1969). These findings were interpreted as giving strong support to the notion that the advantage of the high subjective organizer during memorization is his superior ability to form and retain inter-item associations.

With regard to hierarchically organized material, Bower, Clark, Winzenz, and Lesgold (1969) presented material explicitly in a hierarchical format or randomly. Ss having the organized material recalled about three times as many words as subjects in the random condition. Bower (1970b) has stated that "The advantage of a simple grouping strategy is that the operation can be applied recursively, aggregating together chunks and then groups of chunks into an organized hierarchy. For adults, a hierarchy is an extremely familiar and efficient organizational scaffold, encountered throughout life (in books, library files, etc.) and in science (atomic structure, pyhlogenetic trees, sociopolitical structures, etc.) (p. 42)."

Clearly training students to group together semantically similar material and to form these groups into hierarchies, when possible, would constitute an effective means of promoting retention. Perhaps some of the stimuli used in the above cited experiments would form a basis for the development of training materials.

Memory management. In an instructional setting a student must decide what material should be stored in memory, when it should be stored, and how much effort should be applied to the storing process. In addition, some educationally relevant tasks are more efficiently accomplished if material is forgotten after it has become obsolete. Thus, the subject does not want to "over-store" some material, and in fact, he may even want to consciously forget other material. This loose collection of processes, which will be termed memory management, has not received the empirical attention that it perhaps deserves. There appears to be dramatic individual differences in people's ability to manage their memories, and further, this ability appears to be trainable. For example, Dansereau (1969) gave a large number of subjects a variety of mental multiplication problems (varying from two digit by two digit problems to four digit by two digit problems). Some subjects (about 30%) would spend virtually no time storing the

auditorily presented problem digits prior to beginning their calculations, consequently after the first multiplication or so, they had to again request the problem digits. These same subjects would also fail to rehearse the first intermediate product and would subsequently not be able to recall it for the addition phase. Arithmetic ability aside, some of these subjects (college students) had no idea about their short term memory capacity or about the amount of storage processing required to maintain the material. Prolonged exposure to the mental multiplication task situation led to considerable improvement in this regard on the part of most subjects.

In a short term memory task subjects must decide whether to actively try to store the information upon input or to wait passively until a relatively large amount of information has been presented (using his short term buffers) and then deal with that information actively. Aaronson (1968) found that with a fast presentation rate (3 digits per sec.) Ss tended to listen to a number of digits passively before actively trying to manipulate them. While with a slow presentation rate (1.5 digits/sec.) Ss reported that they tried to actively process each digit as it was presented. Hockey (1973) went one step further, he trained Ss to use either an active (rehearsing and grouping by threes) or passive reception (avoiding all storage activity) strategy. He found that the active storage is best at one digit per second and deteriorates monotonically with increases in rate, while the passive strategy shows the opposite trend improving from one to three digits per second.

Butterfield and Belmont (1971) attempted to relate storage strategies to retrieval in memory for lists of eight consonants. They found that active rehearsal leads to slow retrieval which varies directly with ordinal position and number of items learned. On the other hand, passive attention leads to rapid retrieval which varies with the number of items learned but not with ordinal position. Since this was a self paced task, active rehearsal led to better overall performance.

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These findings are relevant to providing training in memory management, especially for individuals involved in tasks requiring high rates of information input (for example, pilots and air traffic controllers).

A subject must also determine how many items to try to store on each presentation of a multi-trial experiment. Gregg and Simon (1967) showed that subjects who tried to store one or two nonsense syllable pairs (eight pairs presented at a rate of two seconds per pair) per trial (a complete presentation of eight pairs) performed substantially better on a recall test than did those subjects who tried to attend to all pairs on each trial.

If the task is self paced a subject must decide how much time to spend on each item. Belmont and Butterfield (1971), using serial lists of letters, showed that when given freedom to proceed as they wished, normally intelligent Ss increased their pauses the further they went into the list. Retarded Ss maintained relatively constant pause times. Normals retained material at the beginning of the list substantially better than retardeds, with no differences between groups at the end of the list. Long (1974), working on the present research project, extended this research to "good" and "poor" readers. Although both groups spent the same percentage of time on each item in a self paced task, the "good" readers spent significantly more total time on the list. These results will be presented formally in a future project report.

Further work on the memory management processes tapped by the above studies is obviously required. To date, the results are too sparse to draw any specific implications for instructional environments.

As stated earlier and as stated by Reitman, Malin, Bjork, and Higman (1973): "The processes by which information needed is eliminated or set aside are as fundamental to the efficient functioning of an information processing system as are the processes by which information is acquired. Any limited capacity system without the means to select and eliminate is doomed to an unfortunate and

incoherent end; without some mechanism to prevent old information from interfering with the processing of current information, the system's output will eventually bear no sensible relation to its input (p. 140)."

Recent research on directed forgetting has been aimed at this issue of information elimination (see Bjork, 1972; Epstein, 1972 for reviews of this work). In these studies subjects are given cues which indicate that they can forget some or all of the information that has been presented. These cues can apparently be used by subjects in a way that completely eliminates the proactive interference that information presented subsequent to the "forget" cues would normally suffer from the preceding to-be forgotten information.

Since this is new research, no systematic exploration of individual differences and training effects have been reported. Such work needs to be done and pending reasonable outcomes, should be incorporated into a memory management training program. Generally, in developing such programs, emphasis should be placed on cognitive awareness, that is, providing situations that allow the student to become aware of his own processing capabilities, memory capacities, rates of forgetting, and so on. One way of doing this would be to expose a student to a smorgasboard of scaled-down laboratory tasks and to provide ample feedback on his performances.

Retrieval strategies. Even though research on retrieval has been extremely sparse, it is worth mentioning briefly. Studies demonstrating "tip of the tongue" behavior (Brown and McNeil, 1966) and "feeling of knowing" (Hart, 1965) show that a stored item is frequently available, but at least temporarily, not accessible. When an individual encounters such a situation he may give up, randomly search, or attempt to execute a systematic retrieval strategy. Lindsay and Norman (1972) give an example of this latter approach in response to the query: "What were you doing on Monday afternoon in the third week of September two years ago?" After a bit of coaxing by the experimenter, Lindsay and Norman's

imaginary subject gradually homes in on the answer by breaking the query down into a rational sequence of subquestions that prove answerable by various mixtures of actual memories and logical reconstructions of what must have been ("Third week in September - that's just after summer - that would be the fall term..I think I had chemistry lab on Mondays...I remember he started off with the atomic table...", etc.).

The above approach to retrieval is very similar to some of the heuristic techniques studied in the context of human problem solving (in particular "means - ends" analysis). These techniques, which will be discussed in the next section, perhaps should be taught to people faced with the prospects of retrieving available but unaccessible stored information (a common situation at final examination time).

Problem Solving and Creativity.

Skinner (1966) has defined a problem as a question for which there is at the moment no answer. This simple definition can be elaborated by categorizing problems into two major types: closed system problems and open system problems. Bartlett (1958) has suggested that closed system problems are formed in such a way that all the elements for solution are available, and what the problem solver has to do is fill in the appropriate element. In essence, closed system problems are characterized by the existence of an identifiable solution; further, progress towards this solution is usually also identifiable. Examples of closed system problems would include: anagrams, chess, logic and math problems, concept formation, equipment repair (trouble-shooting), navigational problems, etc.

In open-system problems, the problem solver must go beyond the units immediately given in order to "close the gap." Neither the solutions nor progress toward solutions are easily identifiable with these types of problems. Examples of open system problems, which are usually studied under the rubric of "creativity" would include: determining unusual uses for common objects, creating cartoon captions and movie titles, inventing a new device or product, writing a term paper, etc.

Both of these types of problems are faced by students in class and on the job. Strategies related to both types will be discussed in this section.

Closed system problem solving. In this sub-section we will discuss an overview of closed system problem solving processes, factors influencing these processes, specific strategies, and training.

An overview of closed system problem solving processes - The first task for the problem solver is to accurately perceive the nature of the problem and to translate this problem into an internal problem space. This problem space consists of a set of states of knowledge (for example, potential board positions in chess) to which the problem solver may attain. The problem solver's search for a solution is then an odyssey through the problem space, from one knowledge state to another. This internal space is created by appropriately interpreting the task constraints, rules of the game, etc. and combining this interpretation with prior experience in solving identical or similar problems. This process of understanding and interpreting the problem is probably the most crucial step to solution.

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Following creation of the problem space, the solver must recall and/or construct appropriate strategies for operating on this space. Specifically, he must arrive at ways of evaluating the appropriateness of knowledge states and ways of transforming one state into another (in chess these transformation methods would be the set of legal moves, in other problems such methods are not a priori defined).

Once a number of strategies have been generated the individual must select one or more for implementation. During and following this implementation the problem solver must periodically evaluate his progress and make changes in the problem spaces and associated strategies depending on these evaluations (ability to alter spaces and strategies would be analogous to the previously discussed concept of reading flexibility).

Factors influencing the problem solving process - Certain aspects of how a problem is worded affect its solution profoundly (primarily the translation into an internal problem space). Woodworth and Sells (1935) and Sells (1936) used syllogisms to show that the characteristic tone set by the syllogism such as the use of the word "all" in both of the following statements often leads to an incorrect conclusion.

All A is B

All C is B

Therefore; all A is C

The above investigators found that this "atmosphere" effect could be alleviated by stating syllogisms more concretely:

All members of the weight lifting team (A) are students (B),

All sorority sisters (C) are students (B),

Therefore, all members of the weight-lifting team (A) are sorority sisters (C).

Along a slightly different line, the original form of an anagram can also strongly influence the difficulty of solution. More specifically, the closer a sequence of letters approximates English the longer it takes an individual to recombine letters into the target word. For example, it typically takes a subject longer to arrive at the target word "ocean" when the original sequence is "canoe" than it takes when the original sequence is "eanoc" (Beilin and Horn, 1962; Ekstrand and Dominowski, 1968 have done work along this line).

Paige and Simon (1966) have demonstrated through protocol analysis, what most of us know subjectively, that the main source of difficulty in solving ninth-grade algebra word problems is the translation of the words into a manipulable equation.

Certainly we should be training students to attend very carefully to the translation process. Further, some of the notions presented in the prior discussion on comprehension could in fact be applied to this process.

A second factor influencing problem solving is the past history of the problem solver. The effect of set or expectancy carried over from solutions to similar problems has been a well studied phenomenon. For example, if we present the following sequence of anagrams to be solved: LECAM, NELIN, and NEDOZ, and then present PACHE, a subject will be more likely to transform PACHE into CHEAP rather than into PEACH (a tranform requiring fewer manipulations). Similarly, Luchins (1942) has shown that giving subjects a series of "water jar" problems with the same solution will lead about 55% of the subjects to employ that solution on subsequent problems that can be solved in a much simpler fashion.

Duncker (1945), among others, has shown that subjects' perceptions of certain objects become so fixed they are unable to use the objects in novel ways during problem solution.

These problems of "set" are analogous to those investigated under the rubric of reading flexibility. Perhaps training to enhance flexibility in one domain will enhance it in the other.

Specific closed system problem solving strategies - In the context of traditional concept formation studies in which a subject is asked to discover an experimenter defined concept such as "one red circle," Bruner, Goodnow, and Austin (1956) have identified two basic strategies that may have some generality beyond this artificial task situation. The two strategies, scanning (partist strategy) and focusing (wholist strategy), are used by subjects in both "selection" (subject determines the sequence of examples to be examined) and "reception" (experimenter determines the sequence) paradigms. In the scanning (partist) strategy the subject selects a portion of a positive instance to entertain as his hypothesis and concentrates his efforts on proving this hypothesis correct. Because the subject needs to scan and remember only the part of each instance that is relevant to his hypothesis, this approach is frequently employed by students. It does, however, have the disadvantage that the subject concentrates only on part of what he sees and is not likely to learn much while he is following a hypothesis that later proves to be wrong.

In the focusing strategy (wholist) the subject selects a positive instance, retains all aspects of it, and attempts to determine which attributes are irrelevant by comparing his retained positive instances to other positive instances. The differences between these two strategies may be clearer in the context of a literature review task. One could go through the recent issues of a likely

journal and scan each article briefly (partist). Or one could, as soon as he came across a useful article, focus on it and then choose other articles in the light of the information obtained from this first positive instance (wholist).

Bourne (1963) and others have found the focusing or wholistic strategy to be more efficient in concept formation studies, but it is not always the most frequently used. Attempts at teaching college students this strategy in order to improve their concept formation performance have been successful (Klausmeier and Meinke, 1968). Perhaps such training would also lead to better performance in more real world tasks such as literature search and "trouble shooting."

Polya (1957) has developed a series of techniques or strategies which are applicable to problem solving in general. These techniques, called "heuristics," are "rules of thumb" for decreasing the extent of an individual's search through his internal problem space. Two of Polya's heuristics, means-ends analysis and planning, have been incorporated into a computer simulated model of human problem solving. The General Problem Solver (GPS), as it is called, appears to emulate quite accurately human behavior on problems in logic (Newell, Simon and Shaw, 1958). It has also been expanded by Ernst and Newell (1969) to solve a variety of other closed system problems.

GPS using means-ends analysis, begins to solve a problem by detecting a difference between the location of a desired goal state (that is, the answer) and the present location of the subject with respect to that goal. If there is no discrepancy, there is no problem. If, however, a discrepancy does exist, the exact nature of this discrepancy has to be determined and a suitable plan formulated to remove the discrepancy. If this plan can not be formulated directly, GPS must first formulate some subgoal that can in fact be met. Thus any problem is first analyzed to discover whether a discrepancy exists

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between "where an organism is now" and "where he would like to be." This analysis gives rise to a series of subgoals, each one of which may require formulation into further less difficult subgoals. This hierarchy of subgoals is then attacked in order of difficulty-beginning with the most difficult and proceeding through to the least difficult. Once all subproblems have been solved, the solution of the original and major problem can take place.

In order to make this heuristic a bit more concrete, consider the following example presented by Newell, Simon and Shaw (1960): "I want to take my son to nursery school. What's the difference between what I have and what I want? One of distance. What changes distance? My automobile. My automobile won't work. What's needed to make it work? A new battery. What has new batteries? An auto repair shop. I want the repair shop to put in a new battery; but the shop doesn't know I need one. What's the difficulty? One of communication. What allows communication? A telephone...and so on."

In GPS an overall grasp of the problem is provided by the "planning" heuristic which consists primarily of changing an originally complex problem into simpler ones. This simplification is carried out by first abstracting the specific problem to more general terms, and then by simplifying the overall structure of the problem so that it can be subjected to a more direct means-ends analysis. Since the abstracting process serves to simplify the problem, this increases the likelihood that any proposed means-end solution will be successful. Solution steps generated at this level can then serve as plans or prototypes for steps to be taken with regard to the original, complex formulation of the problem.

Training - Except for a few efforts in the concept formation domain, there have been virtually no systematic attempts at training general closed system problem solving techniques. Most problem solving training programs, some of which will be reviewed in a subsequent section, have concentrated on training for creativity (open system problem solving). This situation should be remedied. A good starting place for such programs would be to teach Polya's strategies and measure subsequent changes in problem solving performance.

Open system problem solving. The following topics will be discussed separately: overview of open system problem solving processes, factors influencing these processes, and previous attempts at training.

An overview of open system problem solving processes - Generally, researchers have considered four stages of creativity (open system problem solving): preparation, incubation, insight, and verification. The preparation stage is typically restricted to a subject's attempt at understanding the problem through recall of his previous experience with similar problems, etc. (that is, the translation of the problem into an internal problem space). For our purposes this stage will be expanded to include the conscious production of potential solutions through operating on the problem space and preliminary judgments of the adequacy of produced solutions. In many cases, the steps contained within this preparation stage, which are analogous to those involved in closed system problem solving, are sufficient for production of an adequate solution. However, for various reasons, solutions generated at preparation stage may not be sufficient and in some cases the remaining three steps may occur.

The incubation stage may consist of the unconscious production and judgment of solutions. Subjective reports of creative individuals (for example, Ghiselin, 1952; Koestler, 1964) indicate that this incubation period may be facilitated by

alterations in consciousness (sleep, reverie, drug induced states, etc). In fact, Green, Green, and Walters (1973) have drawn a series of inferences to support the notion that alteration of consciousness by brain-wave training (biofeed-back) may potentially enhance creativity. They note that many creative people report effective incubation and subsequent insight in states where visual imagery is enhanced (in addition, responses to a visual imagery questionnaire correlate .21 with responses to a creativity questionnaire, Schmeidler, 1965). Further, Green, Green, and Walters have shown that subjects trained to produce theta brain waves report concomitant increases in visual imagery. They thus conclude that such brain wave training would enhance creativity via enhanced visual imagery, and have embarked on a research program to assess this hypothesis. Perhaps direct attempts at training imagery ability, as well as other imagery enhancement techniques such as mediation training, could be usefully employed in this regard.

At some point during the incubation period the open system problem solver may experience "insight" or "illumination." An unconsciously produced solution has apparently passed some criterion of judged acceptability. Following insight, the problem solver will usually make some attempt to consciously verify or judge the new found solution. Depending on the outcome of this verification the problem may be solved or the problem solving process may be again initiated.

In general, open system problem solving is marked by production and judgment processes occurring at both conscious and unconscious levels. In the next sub-section we will briefly describe factors influencing these processes followed by the presentation of training methods designed to enhance these processes.

Factors influencing open-system problem solving - All of the factors influencing closed-system problem solving would also have an impact on the solution of open system problems. In addition, previous researchers in this area have placed strong emphasis on the characteristics of the individual open system problem solver. To date, clear delineation of the characteristics of creative individuals has been hampered by methodological difficulties, primarily the lack of an adequate measure of creativity. Although presentation of this research in this area and its concomitant problems is beyond the scope of this review, we will briefly present a "thumbnail" sketch of a creative person as synthesized from Dellas and Gaier (1970) and Johnson (1972).

Very generally, the creative person, as measured by peer and teacher ratings, has an IQ of 120 or above, preferes to look at complex, asymmetrical patterns rather than simple, symmetrical ones, maximally scans his environment (that is, widely deploys his attention and attempts to go beyond the perceptual information given), and has the ability to switch back and forth from child-like to adult-like thinking (as measured by responses to Rorschach stimuli). In addition, the creative is generally introverted, intuitive, self-accepting (non-defensive), risky, and impulsive. As stated earlier, the research upon which these creative characteristics are based is very unsatisfactory, thus the above sketch is little more than a set of weak hypotheses. It would be interesting to determine what effects on creativity would arise from a concentrated attempt to manipulate some of these characteristics in supposedly non-creative individuals.

Previous attempts at training open system problem solving - Certainly the greatest effort toward strategy training has been leveled at the creative process. Two studies are relevant to the training of students to prepare (problem translation primarily) for open system problem solving. Hyman (1961) asked engineers to study attempts already made to design a system for recognizing boxes in an automatic warehouse. One group studied these previous attempts critically, in order to make up a list of faults; another group studied them constructively, in order to make a list of useful features. Later, when all subjects were asked to propose their own solutions to this problem, those who had studied constructively produced better solutions.

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A parallel study by Torrance (1964) reached similar conclusions. He asked psychology students to read two articles in psychological journals, either critically or imaginatively, before the middle of the term. Then they had to develop an original idea, theory, or hypothesis and turn it in on the last day of the term. Again, the products of those who had read imaginatively received superior ratings for originality. Although these studies have some obvious flaws, they do contain potentially suggestive implications for education, and probably deserve careful replication and extension.

A number of attempts have been made to improve the quantity and quality of solutions produced in response to an open-ended problem. Most courses in brainstorming (for example, Osborn, 1953) attempt to increase quality and quantity by instructing participants to postpone criticism. Generally, it is assumed that criticism and harsh evaluation will interfere with flexible idea production. Laboratory studies directed toward this issue have usually led to the conclusion that relaxed conditions and instructions not to evaluate produce more ideas and ideas that have a higher mean quality rating (as judged by "experts") than those produced under more restrictive and evaluative conditions (Johnson, Parrott, and Stratton, 1968; Meadow, Parnes, and Reese, 1959; Dentler and Mackler, 1964; Gerlach, Schultz, Baker, and Mazer, 1964). However, at least some researchers have concluded that instructions to "produce more ideas and withhold judgment" lead to a greater number of ideas, but an overall mean decrease in quality (Weisskopf - Joelson and Eliseo, 1961). It is probably the case that these different results are due to differences between the subject populations.

Researchers attempting to evaluate the effect associated with the training of specific idea-producing techniques have focused on Allen's (1962) morphological synthesis approach. This technique requires analysis of the dimensions of the problem followed by a new synthesis. Ideas for improving one feature of the product are listed along one axis of a two-dimensional diagram and ideas for another feature are listed on another axis so that novel

combinations appear at the intersections. In comparison to two other idea-generating techniques, Warren and Davis (1969) found increased productivity and more superior solutions with the morphological synthesis technique. Furthermore, this technique has been included in a large-scale training program for adolescents with apparently favorable results (Davis, Houtman, Warren, and Roweton, 1969).

Perhaps the most extensive attempt to include production training in an educational setting has been made by Crutchfield (1966). He has developed a programmed text for fifth and sixth graders which encourages the children to think about the complex materials presented and directs the reinforcement toward the production of original and relevant ideas. In particular the program is designed to instruct the reader in; the formulation of the problem, the asking of relevant questions, the laying out of a plan of attack, the generation of many ideas, the search for uncommon ideas, the transformation of the problem in new ways, the evaluation of hypotheses, and the openness to metaphorical and analogical hints leading to solutions.

A number of evaluation studies using open-ended problems (Crutchfield, 1966; Olton and Crutchfield, 1969) have found that students trained on the above method ask more questions, generate more ideas, and get higher ratings for creative quality than a matched control group. Naturally "placebo" effects cannot be ruled out in these studies; comparisons with other training methods are necessary.

After a number of ideas have been produced, the open-ended problem solver must judge the solutions in order to provide a basis for selection. A few studies have emphasized this judgment process. These studies have provided "criteria-cued" instructions which spelled out the criteria to be used in evaluating the subject's productions, and in some cases trained subjects on the use of these criteria. Generally, the "criteria-cued" instructions result in reduced productivity compared to nonevaluative instructions, but

also produced a higher average quality and a higher percentage of superior solutions (for example, Johnson, Parrot and Stratton, 1968; Weisskopf-Joelson and Eliseo, 1961; Gerlach, Schultz, Baker and Mazer, 1964).

Stratton and Brown (1972) trained subjects on both morphological synthesis (production) and judgment criteria. Using responses to a request for titles based on a variety of movie plots, they found that the combined training produced solutions of higher mean quality than those with only production training and a larger number of solutions than those with only judgment training. This combined training approach offers some promise and should undergo further exploration.

Conclusions and New Directions

As emphasized in the introduction, educators and researchers in education have devoted the bulk of their efforts toward the development of improved methods of teaching, and have consequently given very little attention to the identification and development of effective learning strategies. This relatively exclusive focus on teaching is extremely unfortunate in light of the apparent ineffectiveness and inappropriateness of many teaching manipulations, and in light of a growing body of research indicating the importance of strategies in accounting for performance in educational tasks. The purpose of this review and synthesis was to delineate our present state of knowledge with regard to learning strategies and to point out possible future directions for research in this area.

In general, the research on learning strategies, especially in the applied areas, has been extremely lacking. In the majority of studies reviewed, the exploration of strategies has almost always taken a secondary role. Consequently, any systematic attempt at exploring strategies in future experiments would importantly contribute to the educational literature.

A number of general suggestions for future work in this area have been gleaned from studies included in this review.

Tests associated with Guilford's Structure of Intellect model could be used to diagnosis deficits in the skills required for appropriate selection and implementation of learning strategies. Specific training methods could then be developed to cope with particular deficits. It should be noted, however, that in addition to skills, training students should be given experience in putting their skills together in the overall strategy utilization process.

Experiments on educational set have shown that students that prefer to learn conceptual structures rather than isolated facts are generally more successful in educational tasks. Training students to be more conceptually oriented in their learning could obviously improve the effectiveness of their educational experiences.

One personality variable that has proven to have a strong relationship with academic achievement is Rotter's concept of internal versus external locus of control. Students who feel their actions primarily determine subsequent outcomes (internals) generally perform better in an instructional situation. It would be necessary to determine if individuals can be trained to adopt a more "internal-like" view of the world. It is likely that such a view is dependent on being able to successfully manipulate the environment; if so, providing individuals with more effective learning strategies may in turn shift their subjective locus of control.

Many cognitive style variables are also related to academic-like performance. Suggestions for future research on styles are exactly analogous to those discussed in the previous paragraph.

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Reception preferences, motivation, prior knowledge, and sex in conjunction with the above mentioned individual difference variables probably strongly influence the utilization of specific learning strategies. Therefore, training programs should be tailored to match the characteristics of the individual student.

With regard to the assessment of specific strategies, the study strategy questionnaire approach has proved to be efficient and economical although probably not terribly precise. Further work is needed using a more empirically based questionnaire as a diagnostic device. Basic psychological research in comprehension, memory, and problem solving would provide the basis for questionnaire items.

In addition, as has been pointed out in the body of the report, this basic research has provided numerous findings which have potential applicability to the improvement of a student's strategies and skills. Naturally further efforts in these directions are required.

The present research program will attempt to incorporate manipulations based on a number of research findings explored in this review. Primarily we will use an extensive, empirically based questionnaire to identify performance effective strategies, and will subsequently develop and assess procedures for training these strategies and others identified in the recent literature.

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